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Water Quality and Fish in two Freshwater Reservoirs (Gennarby and Sysilax) on the SW Coast of Finland

HEINZ-RUDOLF VOIGT

Department of Limnology and Environmental Protection
P.O. Box 62 (Infocenter)
FIN 00014 University of Helsinki-Helsingfors, Finland

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Abstract: The two coastal inlets, Gennarbyviken and Sysilaxviken, were both isolated from their natural Baltic Sea brackish environments during the 1950:s for purposes of freshwater supply of iron and limestone industries, as neighboring communes, cities of Hanko-Hangö and Pargas-Parainen, as well.
In the deep Gennarbyviken impoundment saline brackish-water conditions remained for years especially in the two depths; 24 and 32 m, where even today anoxia still is widely spread in the bigger southern lifeless depth. The values for salinity and conductivity are also still considerably higher in this depth than elsewhere in the reservoir. In the shallow Sysilax basin such traces of the former brackish-water conditions can no longer be observed.
The presence of the fresh water form of smelt (*Osmerus eperlanus* L) s.c. dwarf-smelt (*O. eperlanus* L. m. spirinchus PALLAS 1811) in both reservoirs also points toward the marine origin of the two impoundments as prior to the closure only the bigger brackish-water s.c. "sea-smelt" (*O. eperlanus* L. m. "eperlano-marinus" BLOCH 1782) formerly was regularly observed here.
The growth of the fish in both reservoirs is weak especially for roach, bream, silver bream and perch but the populations are healthy and strong in spite of the poor food resources; plankton and benthofauna.
The fifth documented case of *stomatopapillosis* on eel (*Anguilla anguilla* L.) in Finland was observed in 1998 from the Gennarbyviken reservoir this also being the first known observation of this disease on eel in Finnish fresh water environment. The prevalence of the microsporozoan parasite *Glugea hertwigi* (WEISSENBERG 1911) infecting the smelts seriously are during epidemics of the same order of magnitude in the Sysilax basin (67.5 %) as in other heavily eutrophicated fresh water reservoirs in contrast to the gentle infections among the brackish-water smelts in the marine coastal waters.
The Gennarbyviken inlet being big, long, narrow, deep and fjordlike in contrast to the small, oval and shallow Sysilaxviken cove, both reservoirs are considered valuable also for fishery reasons.
Attempts of introductions of several favorable fish species however have failed in the Gennarbyviken reservoir and in the Sysilaxviken basin only the amount of less desirable cyprinids have increased numerously whilst the size of most fish especially bream, perch and ruffe has decreased noticeable.
The mercury concentrations in the surface sediments of both reservoirs were in accordance with the background level for natural Finnish lakes, 0.05 mg/kg d.wt, with the exception of the two depths in the Gennarbyviken reservoir where the concentrations were slightly higher ranging between 0.08-0.11 mg/kg d.wt. The concentrations of cadmium in the surface sediments of the maximum southern depth in the Gennarbyviken reservoir were more than half as high; 1.4 mg/kg d.wt. than in the northern depth; 1.0 mg/kg d.wt. and for lead the corresponding values were 52 and 27 mg/kg d.wt. respectively.
The concentrations of mercury in the muscle tissue of the carnivorous fish were high and they often exceeded the accepted security levels of 0.50 - 1.0 mg/kg f.wt. in both reservoirs; perch 0.5 and pike 1.6 mg/kg f.wt. in the Gennarbyviken reservoir and in the Sysilax basin the corresponding means were 0.5 and 0.9 mg/kg f.wt.

respectively. The highest values in regard to cadmium concentrations were recorded in the livers of fish from the Gennarbyviken reservoir; perch 2.1 and pike 0.7 mg/kg d.wt. while the corresponding values from the Sysilaxviken basin were 0.12 and 0.05 mg/kg d.wt. respectively. The concentrations of zinc and copper were higher in livers of fish from Sysilax; perch 99 and 9, pike 174 and 14, bream 134 and 58 mg/kg d.wt. respectively than in the liver of the fish from the Gennarbyviken reservoir; perch 88 and 15. pike 145 and 11 mg/kg d.wt respectively. These differences were not that obvious for the other analyzed metals; iron, manganese, lead and nickel.
At the prospect of future plans regarding impoundments of coastal inlets the consequences of such transformations should be taken seriously.

Key words: fresh water reservoirs, water quality, sediments, fish, heavy metals.

INTRODUCTION

Although the number of natural lakes in Finland, also known as "the land of thousands lakes" (JAATINEN 1971) have been counted to 187 888 (RAATIKAINEN 1985, VOIGT 1986) there are over 30 additional man-made lakes; reservoirs, basins and impoundments spread over the country mainly in the northern and western parts (VOIGT 1978). Most, especially the biggest ones, have been constructed solely for the regulation of the waterflow in rivers according to production of electricity by hydro power, e.g. the Lokka and Porttipahta reservoirs in Lapland, whilst the smaller ones were mainly constructed for fresh water supply of communities or local industries or both, e.g. Gennarbyviken and Sysilaxviken impoundments in the coastal zone of SW Finland (Fig. 1.).

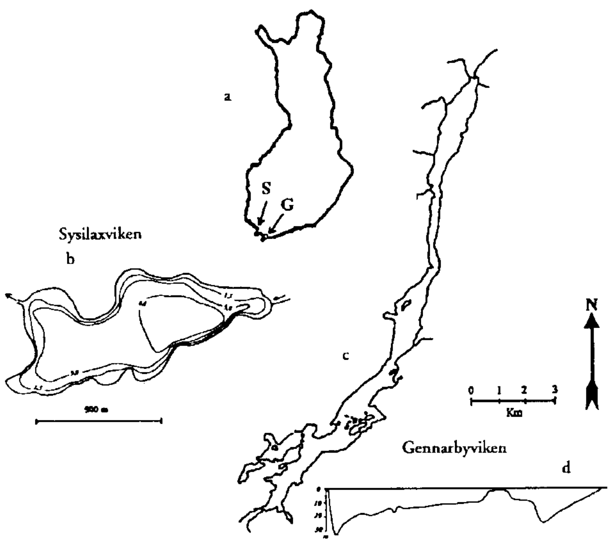

Fig. 1. Location of the two fresh water reservoirs Gennarbyviken (G) and Sysilaxviken (S) on the SW coast of Finland (a). Depth curves for Sysilaxviken (b). Configuration (c) and profile (d) of Gennarbyviken.

There are usually considerable changes in both water quality and fish fauna in such reservoirs when isolated from the brackish sea (RYHÄNEN & al 1960, DAHLSTRÖM 1966, BAGGE & al 1967, WARTIOVAARA 1967, KOLI 1968, PURASJOKI 1968, PURASJOKI & al 1976, HAKALA 1973, AHLBÄCK 1978, LINDHOLM 1975, 1976, VOGT 1978, KENTTÄMIES 1980, KURKILAHTI & al 1990, LINDHOLM & al 1990). Typical consequences are new patterns of the annual temperature cycle, oxygen deficiency in the depths, stepwise decrease of salinity, unstable pH conditions, changes in both color and transparency of the water, etc – all often resulting in an increasing eutrophication of the enclosed waterbody.

There is also a considerable increase of mercury in every known case in Finland in both sediments and biota in man-made reservoirs (LAURILA 1981, VERTA 1981, LODENIUS 1982, LODENIUS & al 1983, ALFTHAN & al 1983, LESKINEN & al 1986, MANNIO & al 1986, SURMA-AHO & al 1986, VERTA & al 1986, KALLIONIEMI 1993, PORVARI 1998 and PORVARI & al 1998) but they do not include the coastal impoundments of a more saline, brackish origin like the Gennarbyviken and Sysilaxviken reservoirs.

Study areas

In 1957 the Gennarbyviken inlet (Fig. 1c. and d.) was isolated from the brackish Gulf of Finland for freshwater supply of the new established iron- and steel factory at Koverhar and for the city of Hanko-Hangö on the Hanko-Hangö peninsula at the SW coast of Finland. The length of the fjordlike and narrow (mean width 650 m) inlet is 16.5 km and the area 10.5 km^2. There are two main depths in the impoundment; Sandudd (25 m) in the northern sub-basin and Norrviken (34.5 m) in the southern sub-basin. The drainage area of the reservoir is 120 km^2, including the total area of 5.4 km^2 for a few smaller forest lakes (SORMUNEN & al 1972).

The Sysilaxviken inlet (Fig. 1b.) was isolated from the brackish Archipelago Sea in 1955 for fresh water supply of the limestone mining industry at Pargas-Parainen for the city of Pargas-Parainen in the inner part of the Archipelago Sea, SW Finland. The area of the basin is 2.5 km^2; 1 km long and 300 m width, the maximum depth is only 4 m and the drainage area is 4.9 km^2. The basin was partly connected to the sea until 1968 when a considerably greater part of the outer coastal area was isolated from the sea. This large reservoir (area; 33 km^2, volume 9400 c km, mean depth 2.8 m, drainage area 23.6 km^2) however has no water exchange with the Sysilax basin with the exception of the outflow from Sysilaxviken and is today the actual fresh water reservoir for both the industry and the city (AHLBÄCK 1978, RANTA-AHO 1987).

Thus Sysilaxviken today is more or less a sedimentation basin for the water entering by small brooks through small forests and a cultivated landscape directly from the artificial slaghills of the limestone mining activity.

MATERIAL AND METHODS

Basic old limnological data for both reservoirs consists mainly of a few published documents with limited circulation and numerous unpublished and untreated field data, which have been critically evaluated before acceptation for this study. To enable comparisons the new data from the 1990:s have been collected and treated the same way as the older data.

Water samples were taken by an ordinary Ruttner watersampler with thermometer, bottom samples (fauna and sediments) by an Ekman-Birge corer and the fish were collected with various types of nets. The limnological parameters were established according to Finnish standards (SFS); temperature in degrees of Celcius (°C), oxygen in mg/l (and % of saturation as well) conductivity in mS/m, pH, alcalinity in mval/l, colour as ug Pt/l, transparency (SECCI) in cm, total nitrogen (Tot-N) and total phosporus (Tot-P), both as ug/l.

The fish were measured, weighed and aged due to normal procedure in fish-investigations and the investigated species are; smelt (*Osmerus eperlanus* L), pike (*Esox lucius* L), roach (*Rutilus rutilus* L), rudd (*Scardinius erythrophtalmus* L), bleak (*Alburnus alburnus* L), bream (*Abramis brama* L), silver bream (*Blicca bjoerkna* L), eel (*Anguilla anguilla* L), burbot (*Lota lota* L), perch (*Perca fluviatils* L), pike-perch (*Stizostedion lucioperca* L) ruffe (*Gymnocephalus cernua* L), and three-spined stickleback (*Gasterosteus aculeatus* L).

The seasons used by treating both limnological and fishery data are; early spring (15.3.-20.4.), spring (21.4.-25.5.), summer (26.5.-15.9.), autumn (16.9.-30.11.) and winter (1.12.-14.3.). From both reservoirs most water quality sampling were performed during summer wherefore data regarding particularly this season is presented entirely. For other seasons only brief comments based on the samplings are given.

Samples for heavy metal analyses were taken only from the surface layer; 0-5 cm of the bottom sediments and from the dorsal muscle tissue and the liver of the fish. Mercury (Hg) was analyzed according to the cold-vapor atomic spectrophotometric method (CVAAS) and the other metals; iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), cadmium (Cd), lead (Pb) and nickel (Ni) were analyzed by atomic absorption spectrometry (AAS). All samples were analyzed in duplicate and the accuracy was assessed by using blanks and reference materials (NBS/SRM 1577a bovine liver and CRM-422 cod muscle). For mercury the results are expressed in mg/kg fresh weight (f.wt.) for both fish muscle tissue and liver but in mg/kg dry weight (d.wt.) for the sediments. All results or metals other than mercury are expressed in mg/kg d.wt.

RESULTS

The old data regarding temperature, oxygen, conductivity, pH, color, transparency and alkalinity of the water are partly published by SORMUNEN & al (1972), reports from VÄSTRA NYLANDS VATTEN OCH MILJÖ (1981-1998)/LÖNNQVIST & al 1981, HELMINEN & al 1989, HOLMBERG 1993-1998, and the unpublished material from 1957-1974 by K.J. PURASJOKI regarding Gennarbyviken, and by AHLBÄCK (1978, 1979), the reports from LOUNAIS-SUOMEN VESIENSUOJELUYHDISTYS (1990-1994)/JUMPPANEN & al 1990-1994, and the unpublished material from 1980-

-1996 at the State Fishery School in Pargas-Parainen regarding Sysilaxviken have all been combined with the present authors own corresponding data from both reservoirs during1994-1999 (VOIGT 1995b, 1996, 1998a, b) to illustrate the development and changes in both reservoirs since the closure. These data are all presented in the tables 1.- 17.

Data on water quality in the Gennarbyviken reservoir during summer season in 1957--1998 are presented in tables 1.-7.

The thermocline separating the warm epilimnion from the cold hypolimnion during summer lasted only from 1957 to 1961 in the northern sub-basin. A similar separation of the two water layers is still visible in the southern sub-basin (table 1.).

During autumn this thermocline has been penetrated by the turn-ower since 1968 in the northern sub-basin when temperatures between 9.0-8.9, 10.1-8.0, 11.8-11.6 have been recorded from surface to the depth in 1968, 1974 and 1995 respectively. In the southern sub-basin such turn-ower effects are not visible. On the contrary a halocline is still separating the two layers at 17 or 24 m deeps.

In early spring the temperature of the surface water varies between 0.3 and 2.0 °C for the entire reservoir and for all water below the surface the variation is between 2.5 and 5.0 °C.

In both sub-basins the temperature in the deeper parts have increased successively since 1959.

In the northern sub-basin the period of oxygen deficiency during summer season is limited to 1958-1961 but periods of low oxygen content of the water in the depth (22 m) have been registered again since 1981.

A total oxygen deficiency has been registered regularly in the southern sub-basin all since 1961 when it reached the level of 22 m. In summer 1996 the first sign of dissolved oxygen in the depth of 30 m since 1957 was observed. In the summer sample of 1997 however oxygen deficiency again was recorded in the depth.

During autumn dissolved oxygen has been very low in the depth of the northern sub--basin only in 1957 (0.2-0.5 mg/l) wherefore since 1960 values between 5.7 and 9.6 mg/l have been recorded for the whole waterbody. In the southern sub-basin oxygen deficiency has been recorded in the deeps (24-30 m) during autumn all since 1960. Oxygen deficiency was observed at 17 m (1958) and 22 m (1963) in the northern sub-basin and at 24-30 m in the southern sub-basin (both years) during winter season observations in 1958 and 1963.

During early spring season the effect of a complete turn-ower is still visible in both sub-basins in 1957 but since 1959 a separation of at least two waterlayers are visible. Oxygen deficiency has been recorded at 17 m (1959) in the northern sub-basin and at 24 m since 1959 in the southern sub-basin. In 1965 dissolved oxygen was registered again in the depth (22 m) of the northern sub-basin.

The period of oxygen deficiency in the northern sub-basin lasted between 1958-1961 at 22 m during summer season. Since 1974 oxygen again has been present in the depth.

In the southern sub-basin the period of oxygen deficiency was introduced in 1961 and it still remains at 30 m (1997) in spite of the first sign of oxygen during summer 1996.

During autumn low values for oxygen saturation (5 %) have been calculated only in 1957 for the depth of the northern sub-basin. For the southern sub-basin similarly low values (2-9%) have been calculated for the deeps (24-30 m) in 1957, 1960 and 1995. Total oxygen deficiency has been calculated for the same deeps in 1968-1974.

The period of oxygen deficiency in the northern sub-basin during early spring season was limited to 1958-1962 at 22 m and to 1958-1959 at 17 m.

In the southern sub-basin there were two periods of oxygen deficiency during early spring; one in 1958 at 28 m and the other considerably longer from 1962-1988 at 30 and 28 m but also at 24 m from 1962 to 1970. In 1997 oxygen was registered at the 30 m depth (tables 2.-3.).

The means for conductivity (mS/m) were calculated for each year to enable a monitoring of the decrease of salinity in the two depths of the reservoir since its closure from the sea in 1957 (table 4.).

In the northern sub-basin the decrease of the conductivity values (< 200 mS/m) were observed immediately in the summer after the closure at deeps above 12 m since 1958 but high values (> 630 mS/m) were observed in the depth at 22 m until 1961.

In the southern sub-basin similarly low values (< 200 mS/m) have been recorded at 7 and 17 m since 1961 but in the deeps (22-24 m) high values (> 200 mS/m) remain until 1974 and in the depth (28-30 m) until 1996.

The first sign of an considerable decrease of the conductivity values for the water in the maximum depth (30 m) of the southern sub-basin was observed in 1993 when the conductivity was measured to 322 being still 927 mS/m in 1988.

During the seasons of winter and early spring the values for the electrical conductivity in the water of the northern sub-basin dropped drastically in 1958; from 552 in 1957 at the surface to < 20 mS/m during the whole observation period 1957-1988. High values (> 550 mS/m) remained only at 17-22 m in 1958-1959 and at 22 m in 1958-1963. Since 1965 the values for conductivity in the northern sub-basin do not exceed 35 m S/m and since 1970 no values > 20 mS/m have been recorded.

In the southern sub-basin values < 140 mS/m are recorded only at depths above 17 m since 1962, in 1963 they are < 75, in 1964 < 60 and in 1970 around 20. In 1988 a value of 33 mS/m was recorded at 24 m. Values higher than 500 mS/m still were recorded at 24 m until 1970, at 28 m until 1981 and at 30 m until 1988.

In the northern sub-basin the values for pH during summer season are considerably below neutral (7.0) at the surface in 1961 and in the deeper waters (12-17 m) in 1961--1981 and the depth (22 m) all since 1961 (table 5.).

Similarly low values are recorded for the water at 17-24 m deeps between 1981 and 1997 in the southern sub-basin but not for the maximum depth (30 m) where neutral values have been registered until 1997. In 1998 surface and bottom values for pH of the water in the southern sub-basin exceeded the neutral value of 7.0.

During early spring extreme low pH values (5.7 and 6.1) were recorded in 1965 and 1981 respectively for the surface water in the northern sub-basin. In the depth (22 m) the values have varied between 6.5 and 7.1 during the observation periods in 1958-1988.

In the southern sub-basin a similarly extreme low pH value also was recorded for the surface water in 1965 and in the years 1970 and 1988 this value was 6.3. At the maximum depth (30 m) high values were recorded in 1957 (7.4), 1964 (7.5), 1965 (7.4) and in 1970 (7.7).

With the exception of the low Pt/l values for color at all depths in 1957 in the northern sub-basin such low values (< 40 Pt/l) have been observed only at 7 m and 17 m in 1961, and at 7 m in 1981 during spring and summer seasons in 1957-1997. Values > 60 Pt/l have been observed only at 22 m in 1964-1970 (table 6.).

In the southern sub-basin values < 40 pt/l were observed not only at all depths in 1957 but also at 17 m in 1958, 7-17 m in 1961, 7-24 m in 1964, and at 7-17 m in 1981.

Values >70 Pt/l were observed only at 28 m in 1970 and in the maximum depth at 30 m in 1970-1997.

Both the lowest (85) and highest (450) SECCI-values for transparency in the Gennarbyviken reservoir were recorded from the southern part of the Gennarbyviken reservoir in 1958 and 1998 respectively (table 7.).

Data on the water quality of the Sysilaxviken basin during summer seasons are presented in tables 8.-15.

During the summer season of the observation period 1978-1996 the warmest water (> 21 °C) in the Sysilax basin was observed at 0.5-3 m in 1992 and temperatures > 19.9 °C were also observed at 1 m 1980 and 1988, at 3 m 1988 and at 0.5 m 1995.

At 4 m close to the bottom all the lowest values for each year were observed. During winter and early spring the temperature in the basin varied between 0.6 °C at the surface and 3.8 °C at bottom. Since 1991 the variation at the bottom has been between 3.0 and 3.8 °C. In spring almost complete turn-owers have been observed in 1978 (12.1-12.5 °C), 1995 (9.3-10.5 °C) and 1996 (7.1-8.7 °C) with the lowest temperature at the bottom all through the observation period (1978-1996) (table 8.).

During summer and autumn seasons a very low value for dissolved oxygen was recorded at 3 m (0.9 mg/l) in 1982 and at 4 m (1.9 mg/l) in 1995. Other values < 7 mg/l were all observed at depths below 2 m in 1980-1988 and 1992-1995. During the seasons winter and early spring low values for dissolved oxygen were recorded from the bottom in 1991, 1993 and 1994; 0.8, 0.9 and 1 mg/l respectively. Shorter periods of total anoxia have been observed at the bottom at 4 m on 12.2. 1992 and in spring, 1.4.-2.5. 1996.

During summer low saturation values were calculated for the water at 3 m in 1982 and at 4 m in 1995. High values were calculated for the surface layer in 1988, 1992 and 1996 but also at 2m in 1988 as at 1 and 2 m in 1996 as well. Except for anoxia at bottom in winter 1992 very low values were calculated for the bottom layer in 1991

(6 %), 1993 and 1994 (7 %). In spring 1996 an other short period of anoxia occurred at the bottom (tables 9. and 10.)

The lowest values of electrical conductivity are all recorded in 1982 and the highest in 1980 and from 1993-1996. The values exceed the values for the water above at the bottom layer (4 m) each year (table 11.).

The highest values of pH in the basin (8.9) were recorded at the surface in 1988 and at 1 m in 1978, 1988 and 1991. The lowest values (7.0) were measured at 2 m in 1993 and at the bottom in 1993 and 1994. All over the pH values were lower at the bottom than in the water of the layers above (table 12.).

High alkalinity values have been observed in the surface layer in 1990 (2.77) and at 3 m in 1992 (3.15). In 1995 and 1996 the highest value for both years were observed in the water from the bottom layer (table 13.)

Values < 40 Pt/l were observed at 1 m 1978, at 0.5-3 m in 1988 and at the bottom (4 m) in 1992. From that year on the values for colour are exceeding 50 Pt/l at all depths in 1995 and at 0.5-2 m in 1996 (table 14.).

The highest (120 cm) and the lowest (45 cm) values for the transparency of the water were both measured during spring in1988 and 1996 respectively. In 1980 and 1992 the high values of 105 and 120 cm respectively were observed during the summer season. During the period of 1994-1996 mean values for the nutrients; total nitrogen (Tot-N μg/l) and total phosphorus (Tot-P μg/l) at 4 m depth were 1100 μg/l Tot-N and 120 μg/l Tot-P (table 15.).

Fish fauna of the Gennarbyviken reservoir

According to HELMINEN & al (1989) the main catches of fish from the Gennarbyviken reservoir consisted of introduced white-fish, pike, perch, pike-perch, eel, bream, burbot, tench, roach, smelt and according to MASALIN (1994) the most frequent species here are roach, rudd, bleak, "small sized bream" (often equal to silver bream), "small sized perch", pike, white-fish, pike-perch, burbot, eel and "trout" (mainly introduced sea trout but also introduced rainbow trout).

Other common species are ruffe (STRANDBERG 1996) and three-spined stickleback (VOIGT 1997). Introduced carp and "galizian tench" also reported from the reservoir (MASALIN 1994) making the number of species in the reservoir to 16.

Only brief comments on growth and food of the fish mainly as citations from VINNI (1999) along with some additional observations on the same material by present author will be given.

The smelt population consists only of small sized and slow growing s.c. "dwarf smelt" or "fresh-water smelt" living only for 2-3 years mainly feeding on cladoceran zoo-plankton and young smelt. White-fish and slow growing bream and silver bream exclusively feeding on cladoceran zooplankton. Same food item also being main food for roach and small perch. Larger perch also consume youngsters of its own and ruffe.

The growth of both perch and ruffe is very slow in the reservoir and they both reach considerable high ages. Ruffe mainly feeds on larvae of insects.

Pike-perch feeding on mainly smelt showed a better growth than pike mainly feeding on perch and roach. Well growing burbots almost exclusively fed on perch.

In july 1998 an eel suffering from *stomatopapillosis* ("cauliflower disease") on its head region was caught from the reservoir and brought to present author. This is the fifth documented observation on this virus induced disease on eel in Finland and the first one on eel from Finnish freshwater.

Cestodan larvae of *Schistocephalus solidus* (MUELLER 1776) were frequently observed in the body cavity of three-spined sticklebacks from the reservoir.

Fish fauna of the Sysilaxviken basin

According to RANTA-AHO (1978) the occurrence in order of frequency of the 10 different species of fish in the Sysilaxviken basin is; roach, silver bream, perch, ruffe, bleak, bream, pike-perch, rudd, pike and smelt. According to the size of these species however the order may be; small sized specimen of smelt, roach, bream, silver bream, perch and ruffe and more of expected natural sized specimen of pike, bleak, rudd, pike-perch, burbot and three-spined stickle-back e.g. in all 12 species.

Here only brief comments on growth and food of these fish will be given although there are numerous unpublished recent data on growth and food of the fish in the Sysilax basin made by students at the State Fishery School in Pargas-Parainen along with the present authors additional observations in 1994-1996.

In the basin as in the great fresh water reservoir outside Sysilaxviken today smelts of only small size, s.c. "dwarf" or "freshwater smelt" are present mainly feeding on zoo-plankton but also young smelt when growing older (3-4 years) as in Gennarbyviken.

In 1995 a severe epidemics caused by the microsporidian parasite *Glugea hertwigi* (WEISSENBERG 1911) was observed not only on the smelts in the Sysilax basin but also in the larger fresh water reservoir outside Sysilax. The prevalence of the infection among diseased smelts in Sysilax was calculated to 67.5 % in spring 1995 but in autumn the same year even mass death occurred among the smelts in both reservoirs. The main food for ruffe in the basin is larvae of insects and for perch it is roach. Together with smelt and all the cyprinids they all constitute main food for the big predators pike-perch, pike and burbot The cyprinids roach, bream and silver bream also growing slow in the basin mainly feed on benthos; insect larvae, mollusks and plants as also their larger sized and better growing relatives bleak an rudd.

In all cyprinids infestations of the cestodan larvae *Ligula intestinalis* L were observed in the body cavity whilst larvae of the digenean trematode *Diplostomum spathaceum* (RUDOLPHI 1819) were common in the eye lenses of perch. Calculated joint mean lengths for both sexes of roach, rudd, bream, silver bream, perch ruffe and pike during 1994-1996 are presented in table 16.

The weak growth of perch, ruffe and pike are noticeable. The three main fish predators pike, pike-perch and burbot all reach high age in the basin; e.g. for burbot ages of 12, pike 16 and pike-perch 18 years were observed.

Attempts to improve the size of desirable fish species perch and bream on behalf of less desirable and/or small sized smelt, bleak, roach, rudd, bream and silver bream have been made by intensive fishing in 1986-1996. The results are presented only as mean weights for each species in table 17.

For bream there may be a slight improvement in size in 1995 but for 1996 the number of breams was far too small to be representative of the whole population. For other species such tendencies of increasing growth are not noticeable.

Metal concentrations

Along with the limnogical and fish sampling in the Gennarbyviken and Sysilaxviken reservoirs in 1994-1998 also sediment samples for heavy metal analyses were taken.

The concentrations of mercury in the surface sediments (0-5cm) of both Gennarbyviken and Sysilaxviken are shown in table 18.

The concentration of mercury in the surface layer of the sediments from the depths in the Gennarbyviken reservoir are slightly higher than in the sediments from the shoals near the shores. For the shallow Sysilaxviken the concentrations of mercury in the sediments are of the same order of magnitude all over the basin.

Heavy metals other than mercury in the surface sediments (0-5 cm) from Gennarbyviken are presented in table 19.

The concentrations of the analyzed heavy metals from the sediments of the two main depths of Gennarbyviken are all higher in the southern than in the northern basin. Only for iron, manganese, cadmium and lead these differences are distinct. Fish from both reservoirs were also analyzed for heavy metal concentrations in muscle tissue and their livers for reasons of health aspects for man (muscle tissue) and aspects of detoxification for the fish (liver).

Mercury analysis were made for muscle tissue of non-predatory fish; bleak, smelt and bream and for predatory species like ruffe, burbot, perch, pike-perch and pike form both reservoirs. The results are presented in table 20.

The muscle tissue of the five bleaks from both reservoirs were analyzed jointly as one sample as were the muscle tissue of the five sticklebacks from the Gennarbyviken reservoir. The joint mercury concentration in the muscle tissue of the sticklebacks was 0.05 mg/kg f.wt. For one eel (*Anguilla anguilla* L), suffering from "cauliflower diesease" (*stomatopapillosis*), this concentration was 1.05 mg/kg f.wt. In muscle tissue of the predatory perch and pike-perch form both reservoirs and pike from the Sysilaxviken the mean values for mercury exceeded 0.50 but they did not reach 1 mg/kg f.wt which was exceeded by pike in the Gennarbyviken reservoir.

The mean concentrations of metals other than mercury in muscle tissue and liver of the fish from the Gennarbyviken and Sysilaxviken reservoirs are presented in tables 21. and 22.

High concentrations of cadmium in both muscle tissue and liver were measured from perch and from the livers of pike and burbot although not of the same order of magnitude as for perch. Other high concentrations measured are iron in liver of perch and zinc in liver of pike.

For perch high concentrations of lead and nickel were measured in both muscle tissue and liver. Other high concentrations measured from the fish in Sysilaxviken are iron in muscle tissue and liver of bream, manganese in muscle tissue of bream an smelt, zinc in livers of bream and pike, copper in muscle tissue and liver of bream and cadmium in livers of perch.

DISCUSSION

Limnology – Gennarbyviken

The dramatic changes in water quality of the Gennarbyviken inpoundment after the closure from the sea in 1957 were observed intensively in the first three-four years by Dr. K.J. PURASJOKI from Tvärminne Zoological Station and SORMUNEN & al (1972) but thereafter the observations are very sporadic and irregular also regarding the parameters. The available data presented in the tables 1.- 7. roughly show the progress in the reservoir from a brackish-water inlet to a slightly eutrophicated fresh water reservoir.

In the upper layers above 12-17 m of the northern sub-basin and above 17 m of the southern sub-basin both temperature and dissolved oxygen values are comparable to conditions in natural fresh water lakes (LAAKSONEN 1970).

In the deep of the northern sub-basin (12-22 m) an considerably change in the water temperature (> 10 °C) has been registered since 1974 but in the southern sub-basin lasting layers of cold water (> 6 °C) have been established in the deep although reduced successively by depth from 17 m (1957), 22 m (1961-1988) and again 24 m (1996), 30 m 1997 and 24 m (1998) indicating a more or less permanent thermocline at 17-24 m.

The observed major decrease of dissolved oxygen at 17 m in the northern sub-basin since 1958 (after the closure) lasted until 1974 wherefore since 1981 oxygen again has been recorded. In the southern sub-basin the periods of low oxygen and oxygen deficiency still lasts in the deeps although some improvements have been registered at 17 m (1974) and at 24 m (1981-1993 and 1997) tables 2.-3. The first recordings of dissolved oxygen at the maximum depth at 30 m in the southern sub-basin were made in 1996 during summer season and in 1997 during early spring.

The influence of the old saline conditions lasted until 1974 in the depth of the northern sub-basin but in the depth of the southern sub-basin these conditions still remain (table 4.) although the values for the electrical conductivity of the water have decreased considerably at 17 m (1974) and at 24 m since 1988.

In the maximum depth at 30 m the first signs of considerable decrease of the values for conductivity were observed in 1993 and at 28-30 m values > 170 mS/m still (1996--1998) are recorded.

Besides thermoclines also haloclines have been observed in the southern sub-basin (table 1. and table 4.) and they both contribute effectively to the stable situation of oxygen deficiency in the depth. The presence of hydrogen sulfide is striking and in the bottom samples from 1997 there were no signs of macrobenthic life either.

The values for pH of the water in the reservoir are today (1998) of the same order of magnitude as when the reservoir was isolated from the sea in 1957 (table 5.).

In between however and at different depths pronounced deviations from the almost neutral average have been observed; pH at the surface in 1961 and 1981, in the northern depth at 22 m since 1961 and at 24 m (1988-1997) in the southern sub-basin, no doubt with consequences for the living organisms in the reservoir. The quality of the inflowing water to the reservoir easily explains the low pH values in the surface layer but for the situation in the deeps of 22-24 m in both sub-basins the explanation is still open. The high values of the pH of the water at the bottom in the southern sub-basin (7.0-7.5) all through the observation period (1957-1998) also requires for explanation.

With exceptions of some samples from the surface the highest values for color ; > 60 mg Pt, have been recorded for the water in the two depths indicating turbidity (table 6.). In 1957-1964 the values for color were higher in the water of the northern sub-basin than in the southern sub-basin. Since 1970 they have been of the same order of magnitude in both sub-basins.

The SECCI values for the transparence of the water at the surface show no clear tendency although a balanced increase by time may be imaginable reaching the maximum observed value of 450 cm of the water in the southern sub-basin in 1998 (table 7.).

Today the water in the upper layer above 17 m is of good quality all over the reservoir but in the maximum depth at 28-30 m in the southern sub-basin not only oxygen deficiency and saline conditions prevail enabling increases of nutrient from the bottom sediments as shown by the high values of both total nitrogen (Tot-N ug/l) and total phosphorus (Tot-P ug/l). From the data of HOLMBERG (1993-1998) mean values were calculated to 4600 ug/l Tot-N and 530 ug/l Tot-P at 30 m in the southern sub-basin for the period of 1993-1997.

Limnology – Sysilaxviken

In Sysilaxviken no constant observations after the isolation from the sea are known but there are some reports regarding limnological data of limited distribution especially made by and for the local limestone mining industry, AB Pargas Kalk OY/ AHLBÄCK (1979), Oy Vesi-Hydro Ab (1981-1983) and LOUNAIS-SUOMEN VESIENSUOJELU YHDISTYS/JUMPPANEN & al (1990-1994).

Most likely the change from a small shallow brackish water inlet into a regulated fresh water basin was considerably more dramatic and rapid than for the bigger and deep Gennarbyviken. According to KALATALOUSSÄÄTIÖ-FISKERISTIFTELSEN 1978 as quoted by RANTA-AHO (1987), it was completed within 3-5 years, since all available data are mostly of a fresh water character (AHLBÄCK 1978) with the exception of the conductivity.

According to the available data for this study (tables 8.-15.) the highest temperatures during spring were recorded in the surface layer at 0-1 m and in the years 1988, 1993 and 1978. Consequently the lowest temperatures were recorded in the bottom layer and in the years 1996 and 1995. There are complete turn-overs of the water in the basin during spring and autumn (RANTA-AHO 1987) although not clearly shown by present data for spring with exception of the years 1978, 1995 and 1996.

During summer high temperature values were predominant in the upper layers with some exceptions in 1988, 1982 and 1987 when temperature maxima were recorded at 3 m. During winter and early spring 1980-1996 the highest temperatures were recorded from the bottom layers all through the season.

The Sysilaxviken basin thus having isolated deep water all through the year although with changed conditions in both epi- and hypolimnon when temperature is concerned. Independently of season periods of low oxygen saturation (1991, 1993-1994) and even oxygen deficiency (1992, 1996) have been observed in the shallow Sysilax basin (tables 9.-10.) all with consequences for the living organisms in the basin.

In 1982 low values (35-38 mS/m) for the conductivity were measured in comparison to previous and following years but in the years 1980, 1993, 1995 and 1996 these values at deeps above 4 m were considerably higher (45-60 mS/m) indicating an increasing tendency from 1993 onwards. In the depth of Sysilaxviken all through the observation period the values for the conductivity were higher (46-69 mS/m) than in the upper layers (table 11.). Also here the increasing tendency by time is obvious. Although the conductivity values often are used as indirect parameters for salinity (e.g. in this study for the situation in the depths of Gennarbyviken) they actually only reflect the amount of dissolved substances as electrical conductivity of the water.

As the incoming water to the Sysilax basin also contains water that has passed through the mining slagghills in the drainage area of the basin it also is loaded by the salts diluted from the slagghills which in this case may explain the considerably higher values for conductivity in the Sysilax basin than the average (6 mS/m) for Finnish lakes HEINONEN & al, 1987). This assumption is also partly supported by the values for pH which in the Sysilax basin due to the limestone environment are considerably higher than the average values for lakes (pH 6.6) in Finland (LAAKSONEN, 1971).

Independently of the observed pH variations during the growth season in spring--summer there appear to be no clear tendencies regarding pH development in the Sysilax basin although a discreet decrease by time during the 1990:s (pH more often below 8 than previously during the observation period 1978-1996) may be imaginable (table 12.). Weather this could be explained by e.g. decreased pH values in the inflowing run off water from the forest areas within the drainage area of the basin or by acid rain over the area has not been considered in this study. The observed lowest pH values for each year in the bottom layer at 4 m require an explanation especially in connection to the facts regarding the eutrophication of the basin as they should at least partly be reflected by the amount of the nutrients in the basin.

There is no pronounced tendency of in- or decreasing alkalinity values for the water in the Sysilaxbasin during the observation period in 1989-1996 (table 14.) but they all by far exceed the average values of 0.5 mval/l for lakes in Finland (JÄRNEFELT 1958).

They also exceed the corresponding surface values of 1.07 and 1.33 mval/l as measured in 1983-1984 by RANTA-AHO (1987). All the highest values were recorded from the deeper water and they all emphasize a powerful strength against any form of acidification of the basin.

With exception of values for color, 34 mg Pt/l at 1 m in 1978, all water layers above 4 m in 1988 and at 4 m in the depth in 1992 (35 mg Pt/l) all other values recorded from the basin are more or less of the same order of magnitude, range; 40-60 Pt/l at 1-3 m in 1978-1987 and range; 50-60 Pt/l at 3 m in 1992-1996. Both periods indicating a slight increase in time especially within the surface layer during the 1990:s (60-70 mg Pt/l) (table 14.). These values however all lay far below the averages reported for the basin during the years 1983-1984; 81 and 67 Pt/l respectively (RANTA-AHO 1987) and the average value for color of all the lakes in Finland; 90 mg Pt/l (LAAKSONEN 1970).

During the observation period 1978-1988 the transparency of the water (SECCI cm) in the Sysilax basin was higher in spring (45-120 cm) than in summer (70-105 cm) as in 1983-1983 reported by RANTA-AHO (1987) but since 1990:s the opposite is the case (45-60 and 70-120 cm respectively) eventually indicating a prolonged growth season in the basin (table 15.).

The mean values for both total nitrogen; 1100 ug/l and total phosphorus; 120 ug/l at 4 m depth in the Sysilax basin indicate an eutrophication. These values by far exceed the corresponding values calculated for the maximum depth at 24 m in the northern sub--basin of the Gennarbyviken reservoir but they are considerably lower than the values calculated for the maximum depth at 30 m in the southern sub-basin of the reservoir.

The differences between the two fresh water reservoirs Gennarbyviken and Sysilax thus are considerable regarding hydrography and most limnological parameters studied which all reflects on flora and fauna including fish and fish resources of both reservoirs.

Fish – Gennarbyviken

In spite of the massive introduction of preferable fish species into the Gennarbyviken reservoir like various forms of whitefish (*Coregonus lavaretus* L *coll.*), vendace (*C. albula* L), pike and pike-perch also "trout"; mainly common sea trout (*Salmo trutta* L) but also rainbow trout (*Oncorhynchus mykiss* WALBAUM) including also splejk trout (*Salvelinus namaycush* WALBAUM x *S. fontinalis* MITCHILL), elvers of common eel (*Anguilla anguilla* L), carp (*Cyprinus carpio* L) and "galizian tench" (*Tinca sp*) which have been introduced into the reservoir more or less regularly all since the 1960:s (BENGELSDORFF 1991) as shown in table 23, the most common species still appear to be perch, ruffe and bream all three of small size and bleak.

Pike is also regarded common whereas all other introduced species and the preferable burbot are regarded not as common as desirable (MASALIN 1994). With the exception of eel the introduced species do not manage to escape from the reservoir at the gate of the dam during regulated outflows (STRANDBERG 1996).

In the Gennarbyviken reservoir roach, bleak, "small breams" (including both bream and silver-bream), small perch, whitefish, pike and pike-perch are "common" but in order of "importance" according to the fishing people here the species are; perch, pike,

pike-perch, whitefish, burbot, eel, trout and bream (MASALIN 1994). Ruffe and smelt are both also regarded "common" by STRANDBERG 1996 and VINNI 1999 and so are threespined-sticklebacks too (this study) making the number of species in the reservoir to 14-16 whether carp and tench are included or not.

Age and growth of the fish in the Gennarbyviken reservoir have been studied by JAHNUKAINEN (1982) who concentrated on pike and by VINNI (1999) who also examined pike, pike-perch, perch and ruffe; e.g. average pike females age 3 years reach 25 cm, 6 years 40 cm, 12 years 60 cm and 18 years reach 80 cm, for pike-perch corresponding data are; 2 years 15 cm, 3 years 20 cm 4 years 25cm and 5 years 30 cm, for perch 3 years 12 cm, 4 years 15 cm, 6 years 20 cm and 9 years 25 cm and for ruffe 3 years 7 cm, 6 years 9 cm and 8 years 10 cm (VINNI 1999). All studied species grow considerably slower in the Gennarbyviken reservoir than they do in the brackish water outside the reservoir (JAHNUKAINEN 1982 and VINNI 1999).

There are no previous observations on the food of the fish in Gennarbyviken except the notes regarding pike by JAHNUKAINEN (1982) where he states that the pikes mostly feed on smelt, roach, perch and ruffe. According to VINNI (1999) the pikes consume mainly roach and perch whereas pike-perch almost exclusively feed on smelts as do burbot on perch. The importance of zooplankton, mainly the cladoceran *Bosmina* sp. for the non-predatory fish and young perch has clearly been pointed out by VINNI (1999) and is one of several marks of the impoverished fauna of the reservoir including the benthofauna (VOIGT 1997).

Three-spined sticklebacks were observed with the cestodan larvae of *Schistocephalus solidus* (MUELLER 1776) in the body cavitity in the Gennarbyviken reservoir.

The observation of *stomatopapillosis* on an adult eel from the reservoir is the first documentation of this disease from fresh water in Finland. Previously only four documentation of the disease on eel in Finnish coastal waters are known (VOIGT 1995 a) and as the occurrence of this virus induced disease on eels has been related to a combination of increased water temperature (thermopollution) and eutrophication (BOGOVSKY 1992, VOIGT 1994) its presence in the Gennarbyviken reservoir should be regarded as a warning.

Fish – Sysilaxviken

There are 12 species documented as permanently present in the Sysilaxviken basin; smelt, pike, bleak, roach, rudd, bream, silver bream, perch, pike-perch, ruffe (RANTAAHO 1979, 1987), burbot and three-spined stickleback (this study) and of which a limited growth has been documented especially for bream, roach, rudd, perch and ruffe (RANTA-AHO 1979, 1987 and this study). For smelt there even has been a change from the bigger brackish-water form (incorrectly named "sea" smelt; *Osmerus eperlanus* f. "*eperlano-marinus*" BLOCH 1782) into the smaller fresh-water or "dwarf" form (*O. eperlanus* f. *spirinchus* PALLAS 1811).This phenomena has previously been observed by REDEKE (1922) and it is mentioned by e.g. LILLELUND (1961) and pointed out by VOIGT (1972) but actually it has never been studied properly. In lakes and reservoirs "dwarf smelts" mainly feed on zooplankton but turn to cannibalism as adults. The fresh water smelts are common in most lakes of the inner parts of Finland and they have both lesser growths and shorter life cycles than the bigger brackish-water "sea smelt" (VOIGT 1972).

With the exception for bleak and rudd the growth of all cyprinids as perch and ruffe as well in the basin is weak in comparison to the growth of the same species in the brackish water along the Finnish SW coast (e.g. present authors unpublished data).

Similar to Gennarbyviken the growth of pike in the Sysilaxviken basin is poorer than that of the other big predators pike-perch and especially burbot although all three species reach large size i.e. equal to high age in both reservoirs.

The food of roach, perch, pike-perch and pike in the great fresh-water reservoir outside Sysilaxviken has been studied previously by PAKKANEN (1979, 1984) but for the fish in the Sysilax basin only unpublished data produced by the students and collected by the teachers at the State Fishery School at Pargas-Parainen are available. According to this data and present authors own results the feeding behavior of the fish in Sysilaxviken briefly are as follows; roach feeding mainly on plants, larvae of insects and zooplankton, bream and silver bream consuming mainly mollusks, perch consuming mainly small roach, bleak, smelt, perch and larvae of insects and the big predators pike--perch, pike and burbot all three feeding on the smaller fish in the basin.

Among the smelts in the Sysilaxviken basin as in the bigger fresh water reservoir outside the basin a severe lethal epidemic caused by the microsporidian *Glugea hertwigi* (WEISSENBERG 1911) was observed by the author in 1995 and according to local fishermen similar "mass deaths" among smelts have also been observed previously. Infections by this microsporozoan parasite are common among fresh-water smelts from mainly eutrophicated lakes all over its distribution area (e.g. SCHÄPERCLAUS & al 1979, VOIGT 1989) but they appear seldom among the big brackish-water smelt in brackish-water environments (e.g. HALEY 1953, VOIGT 1989). Other noteworthy infestations of parasites are the observations of the meta-cercarian larvae of the digenean trematode *Diplostomum spathaceum* (RUDOLPHI 1819) in the eye lenses of perch in the Sysilaxviken basin and of the cestodan larvae of *Ligula intestinalis* (L) in the body cavity of most cyprinids; roach, bream and silver bream in the basin.

In spite of the great efforts regarding intensive fishing in the Sysilax basin the results of the massive measure are modest as for all essential less desirable species the catches still are considerable but the size of most of the fish still remain small.

Summarizing the fish in both reservoirs have a weak growth compared to the growth of the same species living in the brackish water outside the reservoirs mainly due to the similarly poorer fauna in the reservoirs. Pike and ruffe having a considerably slower growth in the Gennarbyviken reservoir than in the Sysylaxviken basin. For perch and pike-perch this difference in growth was not that obvious.

With the exception of the observed severe *Glugea*-epidemics among the smelts in the Sysilaxviken basin the few and mostly harmless infestations of macroscopic parasites indicate a relatively good health condition of the fish in both reservoirs.

Metals – Gennarbyviken and Sysilaxviken

In contrast to numerous works on heavy metals and especially mercury in both sediments and biota of man made artificial lakes and reservoirs in Finland (LAURILA 1981, VERTA 1981, VERTA & al 1986, LODENIUS 1982, ALFTHAN & al 1983, LESKINEN & al 1986, MANNIO & al 1986, SURMA-AHO & al 1986, VERTA & al 1989, KALLIONIEMI 1993, PORVARI 1988 and PORVARI & al 1998) information on this topic is scarce regarding reservoirs isolated from the brackish water along the Finnish coast.

The range for the concentrations of mercury in the surface sediments (0-5 cm) from the littoral (1-4 m) of the Gennarbyviken reservoir were measured to 0.02-0.04 mg/kg d.wt. In the sediments from the two depths of the reservoir (24 and 32 m respectively) this range was 0.08-0.11 mg/kg d.wt. In the surface sediments of the shallow Sysilaxviken (max. depth 4 m) the concentrations of mercury varied between 0.05-0.06 mg/kg d.wt.

All these values are below the corresponding values reported from other artificial man-made fresh-water lakes in Finland e.g. lake Porttipahta mean 0.23 mg/kg d.wt and lake Kalajärvi 0.27 (LESKINEN & al 1986), "young reservoirs" 0.10 mg/lg d.wt. (SURMA-AHO & al 1986), "natural lakes" in Finland; 0.20 mg/kg d.wt. (SURMA-AHO & al 1986), Finnish "headwater lakes"; 0.36 mg/kg d.wt. (VERTA & al 1990) but they instead slightly exceed the values recorded for unaffected lakes e.g. lake Pyhävesi in the Finnish lake district; 0.03 mg/kg d.wt. (LODENIUS 1980).

For metals other than mercury in the sediments of impounded brackish water inlets the information is even more scarce whereas the analytical results regarding the Gennarbyviken reservoir in this respect are unique. Compared to the mean values for Finnish "headwater lakes" (HL) of the subregion "south" in southern Finland, VERTA & al 1990 the results (mean values) from the Gennarbyviken reservoir (GB) are presented in table 24.

The high values of zinc, copper and especially nickel in the surface sediments of Gennarbyviken require along with the values for iron (mean 37 350 mg/kg d.wt.) and manganese (mean 835 mg/kg d.wt.) more attentions in further studies of the reservoir as they with the exception of copper and lead, exceed the values of the preliminary results regarding the concentrations of these metals in the surface sediments outside the reservoir (present authors unpublished preliminary data).

The concentrations of mercury in the muscle tissue of the fish from both reservoirs did not exceed the stipulated level of 0.50 mg/kg f.wt. for human consumption more often than once a week (NATIONAL BOARD OF HEALTH, 1971, 1981) in the non--predatory species; three-spined stickleback, bleak, smelt, bream and ruffe plus the predatory burbot as well. In both reservoirs however the concentrations of mercury in the predatory species perch, pike-perch, pike and eel exceeded the recommended Finnish safety levels of 0.5 - 1.0 mg/kg (f.wt.) (NATIONAL BOARD OF HEALTH 1971, 1981, EUROPEAN COMISSION 1993) and they by far exceed the corresponding levels of mercury in the same species e.g. perch 0.20 and pike 0.30 mg/kg f.wt living in the brackish water of the sea directly outside these two reservoirs, sampled and analyzed during same periods (VOIGT 1998 c, d).

Compared to results from other man-made lakes and fresh water reservoirs in Finland the values for mercury in pike from Gennarbyviken and Sysilaxviken are of the same order of magnitude (LODENIUS & al 1983, LESKINEN & al 1986, PORVARI 1998). Regarding the other investigated species from the two reservoirs the available information at present is still uncompleted.

Whether the intensive fishing in the Sysilax basin has led to a decrease in the mercury concentrations of the fish as shown for intensive fishing in Sweden by GÖTHBERG (1983) can no longer be proved but the fact is that the mercury concentrations in the fish from the Sysylax basin are lower than in the fish from the Gennarbyviken reservoir where no such intensive fishing has taken place.

The results regarding metals other than mercury indicate higher concentrations in the fish from the Sysilaxviken basin than in the fish from the Gennarbyviken reservoir with the exception of cadmium for which the concentrations in the liver of the investigated species; perch, pike and burbot were noticeably higher. The comparable high concentrations of cadmium for perch from the Gennarbyviken (0.22 mg/kg d.wt. muscle and 2.1 mg/kg d.wt. liver) require more attention although calculated to fresh weight (0.04 mg/kg muscle and 0.42 mg/kg liver respectively) the concentrations in the muscle tissue do not reach the security level (0.1 mg/kg f.wt.) for edible fish in Finland (MINISTRY OF TRADE AND INDUSTRY 1984). In fish from the Sysilaxviken basin the concentrations of cadmium are higher in both muscle tissue and livers of bream and perch than from other investigated species. In perch from the Sysylaxviken basin the concentrations of lead and nickel were considerably higher than in perch from the Gennarbyviken reservoir. For smelt from the Sysylaxviken basin the concentrations of nickel in the liver were extremely high (mean 4.2 mg/kg d.wt.) which calls for further investigations.

As all the material from the Gennarbyviken reservoir and the Sysilaxviken basin has been far too small there has been no statistical treatment of the analytical results.

For metals other than mercury there are even less information regarding concentrations in fish from man-made lakes or reservoirs but compared to the concentrations in livers of fish from acidic ($pH < 5.2$) and circa neutral lakes ($pH > 5.9$) in Finland (VERTA & al 1990) the results from both Gennarbyviken and Sysilaxviken are of the same order of magnitude regarding zinc and copper for perch and pike. For cadmium, lead and nickel the concentrations in the livers of perch and pike are considerably higher in these reservoirs than those reported from the referred lakes.

As these two reservoirs were planned not only for fresh water supply but also for fishery and recreation the consequences of the transformation from marine, brackish water inlets into fresh water basins should be taken seriously if and when plans for constructions of new such impoundment are to be considered again.

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Table 1. Temperature (°C) of the water at different depths for both the northern (N) and southern (S) sub-basins of the Gennarbyviken reservoir in summer during 1957-1998

Depth	1957	1958	1961	1974	1981	1988	1993	1996	1997	1998
(N) 1m	18.1	13.8	14.3	19.7	19.9	16.8	15.7	15.3	17.5	
7 m	8.6	14.1	14.2	16.5	19.3	16.6	15.5	15.3	17.5	
12 m	4.2	4.6	14.1	12.7	14.8	12.2	15.3	14.3	12.2	
17 m	3.8	4.3	8.9	12.3		10.3				
22 m	3.5	5.0	4.8	12.1	11.6	9.8	10.5	11.1	11.3	
(S) 1 m	17.9	14.1	14.6	18.0	20.0	16.8	16.1	16.4	17.8	20.2
7 m	15.1	7.4	14.5	17.3	19.6	16.8	15.9	16.7	17.8	
17 m	3.3	3.2	13.0	7.6	9.0	7.5	9.7	8.9	10.2	11.5
22 m	1.8	3.3	5.9	4.1						
24 m	1.8	2.8	4.0	4.6		5.9	7.3	5.5	10.2	8.5
28 m	1.9	2.7	3.8	5.0	5.4	6.2				
30 m	2.0	2.6	3.8	5.4	4.6	4.8	7.0	4.5	5.4	5.2

Table 2. Dissolved oxygen (mg/l) in the water of both northern (N) and southern (S) depths of the Gennarbyviken reservoir in summer during 1957-1997

Depth	1957	1958	1961	1974	1981	1988	1993	1994	1996	1997
(N) 1 m	9.2		9.4	9.0	8.5	8.9	9.2	8.2	8.6	7.9
7 m	2.6	10.0	10.4	7.0	8.2	8.3	8.9		8.4	7.2
12 m	0.5	5.4	8.6	5.1	3.0	2.3	8.5	1.2	5.7	0.8
17 m	0.7	1.0	1.4	4.9		1.4				
22 m	0.6	0.1	0.1	4.2	2.6	0.9	2.0	0.8	0.7	0.7
(S) 1 m	8.9	11.6	8.6	9.2	9.2	8.6	9.4	8.4	8.5	7.8
7 m		9.2	8.3	9.0	9.0	8.2	9.3		8.7	8.0
17 m	3.0	7.7	8.7	5.6	6.5	3.7	6.0	5.6	4.4	4.5
22 m		0.4	0.1	1.2						
24 m		0.6	0.1	0.1	3.8	1.8	4.5		0.6	4.6
28 m			0.1	0.1	0.1					
30 m	1.8		0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.1

Table 3. Oxygen saturation (%) in the water of both northern (N) and southern (S) sub-basins of the Gennarbyviken reservoir in summer during 1957-1997

Depth	1957	1958	1961	1974	1981	1988	1993	1996	1997
(N) 1 m	96	101	95	102	93	92	93	86	83
7 m	26		104	71	89	85	89	84	75
12 m	4	43	86	47	30	21	85	56	7
17 m	6	8	12	46		13			
22 m	5	0.1	0.1	38	24	8	18	6	6
(S) 1 m	95	116	88	100	101	89	96	87	82
7 m		80	85	96	98	85	94	90	84
17 m	25	60	39	49	56	31	53	38	40
22 m		3	0.1	2					
24 m	4	0.1	0.1	31	14	37	5	41	
28 m			0.1	0.1	0.1				
30 m	13		0.1	0.1	0.1	0.1	0.1	2	1

Table 4. Conductivity (mS/m) of the water in the northern (N) and southern (S) depths of the Gennarbyviken reservoir during summer in 1957-1998

Depth	1957	1958	1961	1974	1981	1988	1993	1996	1997	1998
(N) 1 m	493	192	70	15	12	11	13	14	13	
7 m		190	67	15	11					
12 m		471	67	16	11					
17 m	578	547	212	16	11					
22 m	687	666	686	16	11	12	14	15	13	
(S) 1 m	784	392	150	23	14	13	15	15	15	15
7 m		464	148	23	14					
17 m	805	603	156	46	15	16				
22 m		858	908	200						
24 m	893	889	958	870		29	24		15	20
28 m	858	970	912	840						185
30 m		839	971	925	910	927	322	230	176	351

Table 5. pH values of the water of the Gennarbyviken reservoir during summer in 1957-1998

Depth	1957	1958	1961	1981	1988	1993	1996	1997	1998
(N) 1 m	7.0	7.1	6.5	7.1	7.0	7.1	7.0	7.1	
7 m	7.0	6.9	6.8	7.2					
12 m	6.9	6.9	7.0	6.7					
17 m	6.8	7.0	6.6						
22 m	7.0	7.1	6.7	6.5	6.4	6.5	6.3	6.4	
(S) 1 m	7.2	6.9	7.3	7.6	7.0	7.2	7.1	7.1	7.8
7 m	7.3	7.0	7.3	7.5					
17 m	7.0	6.9	6.9	6.7					7.0
24 m	7.5	6.9	7.3		6.6	6.6	6.7	6.4	7.0
28 m	7.2	7.1	7.3	7.3					7.3
30 m	7.5	7.2	7.1	7.2	7.3	7.0	7.0	7.0	7.4

Table 6. Color values (Pt/l) of the water in the northern (N) and southern (S) sub-basins of the Gennarbyviken reservoir in spring – summer 1957-1997

Depth	1957	1958	1961	1962	1964	1970	1981	1988	1997
(N) 1 m	20	45	45	65	60	40	40	40	
7 m		45	30	45	40	60	30		
12 m	25	42	30	45	40	40	40		
17 m		40	35	50	50	50			
22 m	32	45			70	150	60	50	
(S) 1 m	15	40	70	65	40	40	40	40	40
7 m		40	20	45	15	40	30		
17 m	20	32	20	45	20	40	20		
22 m			40	45	25	40			
24 m			40					45	50
28 m						140			
30 m	11					120	125		90

Table 7. Transparency (SECCI cm) of the water in the northern (N), central (C) and southern (S) parts of the Gennarbyviken reservoir during spring – summer 1957-1998

YEAR	1957	1958	1959	1962	1965	1970	1981	1988	1993	1997	1998
North			135	130	175	170	150	190	200	100	
Centr			150	100		210		230	300	170	
South	315	85	180	130	260	210	215	260	300	200	450

Table 8. Temperature (°C) values of the water in the Sysilaxviken basin during 1978-1996

Depth	1978	1980	1982	1987	1988	1989	1991	1992	1993	1994	1995	1996
0.5 m	18.5				18.9		14.9	21.3	14.0	16.6	20.4	15.0
1 m	18.9	20.0	18.0	15.7	20.1	19.1	17.2	21.2	18.0	17.3	18.9	15.0
2 m	17.8	19.9	18.0	15.7	18.3		15.8	21.1		17.2	15.8	14.9
3 m	16.3	19.8	18.2	16.7	22.1	18.1	17.0	20.0	16.7	15.7	12.7	12.8
4 m	15.8				16.2			16.9			10.7	11.7

Table 9. Dissolved oxygen (mg/l) in the water of the Sysilaxviken basin in summer and autumn seasons during 1978-1996

Depth	1978	1980	1982	1987	1988	1989	1991	1992	1993	1994	1995	1996
0,5 m	11.3						10.5	13.4		10.6	11.6	14.4
1 m	11.6	9.9	8.0	9.0	11.1	10.3	11.7	13.9	10.5	10.5	10.7	14.3
2 m	11.0	9.0	4.5	5.7				6.4		10.5	8.2	14.0
3 m	8.2	5.5	0.9	5.5	9.2	8.0	8.0	6.2	6.6		6.3	9.7
4 m	8.1				3.2			6.2			1.9	6.6

Table 10. Oxygen saturation (%) in the water of the Sysilaxviken basin in summer during 1978--1996

Depth	1978	1980	1982	1987	1988	1989	1991	1992	1993	1994	1995	1996
0.5 m	123				158		106	148		128	135	149
1 m	124	109	84	100	132	101	122	129	111	118	109	148
2 m	119	97	50	53	155			122		120	74	145
3 m	78	60	10	60	98	80	83	76	65	19	47	99
4 m	69				31			43			15	67

Table 11. Conductivity (mS/m) of the water in the Sysilaxviken basin during 1978-1996

Depth	1978	1980	1982	1988	1989	1991	1992	1993	1994	1995	1996
0.5 m	44			42			46	52	48	52	55
1 m	45	53	35	42	45	46	45	45	44	51	53
2 m	45	53	37	42		46	45	49	48	52	59
3 m	47	57	38	44	54	46	48	51	52	53	60
4 m	49			46			53	64	64	55	69

Table 12. pH values of the water in the Sysilax basin during 1978-1996

Depth	1978	1980	1982	1987	1988	1989	1991	1992	1993	1994	1995	1996
0.5 m	8.7				8.9	8.3		7.9	7.4	8.3	8.3	8.3
1 m	8.9	8.2	8.7	8.6	8.9	8.2	8.9	7.6	7.7	7.5	8.4	8.1
2 m	8.8	8.1	8.8	8.4		8.4	8.8	7.7	7.0	7.8	8.3	8.0
3 m	8.8	7.7	8.9	7.8	8.7	8.4	8.7	.5	7.2	7.2	7.9	7.9
4 m	8.3				8.0	7.2			7.0	7.0	7.7	7.7

Table 13. Alcalinity (mval/l) values of the water in the Sysilax basin during 1978-1996

Depth	1978	1989	1990	1991	1992	1993	1995	1996
0.5 m	1.97	2.27	2.77	2.55	2.10	2.53	2.10	2.48
1 m							2.15	2.49
2 m					2.53		2.13	2.30
3 m					3.15		2.16	2.48
4 m							2.39	2.66

Table 14. Colour values (Pt/l) of the water in the Sysilax basin during 1978-1996

Depth	1978	1980	1987	1988	1992	1995	1996
0.5 m				35	60	70	60
1 m	34	58	60	35	60	57	55
2 m	45	51	40	35		54	50
3 m	48	65	50	35	50	55	45
4 m				60	35	55	45

Table 15. Transparency (SECCI cm) of the water in the Sysilax basin during spring and summer seasons in 1978-1996

SEASON	1978	1987	1988	1989	1991	1992	1993	1994	1995	1996
Spring	95		120		60	60	55	55	55	45
Summer	70	60	105	80	95	120	70	85	70	70

Table 16. Length (cm) of roach (*Rutilus rutilus* L), rudd (*Scardinius erythrophtalmus* L), bream (*Abramis brama* L), silver bream (*Blicca bjoerkna* L), perch (Perca fluviatils L), ruffe (*Gymnocephalus cernua* L), and pike (*Esox lucius* L) at ages 1 – 13 in the Sysilaxviken basin 1994-1996

AGE	1	2	3	4	5	6	7	8	9	10	11	12	13
Roach	4.2	6.5	9.1	11.8	13.9	16.1	19.3	20.3	21.2	22.3	22.9	23.7	24.5
Rudd	5.5	8.1	10.3	12.5	16.3	21.3	24.2	27.0	30.9				
Bream	5.5	9.6	13.0	16.8	21.3	25.1	28.0	31.5	43.3	36.8	40.0	44.2	45.5
S-bream	3.2	4.1	4.9	6.0	8.7	10.8	11.5	12.9	14.1	15.4			
Perch	5.1	9.2	11.4	14.2	17.6	20.6	22.5	23.9	24.8	25.2			
Ruffe	2.3	4.5	7.6	9.8	11.5	13.1							
Pike	14.2	19.6	29.6	35.6	44.3	51.5	58.8	66.3	76.2	83.1	92.5	97.8	120.2

Table 17. Mean weights (g) of the fish intensively caught from the Sysilaxviken basin during spring and summer in1986-1996

YEAR	1986	1987	1988	1992	1993	1994	1995	1996
Smelt	5.5	7.5		2.8	3.3	7.6	4.4	4.3
Bleak	11.5	11.2	9.9	12.6	8.7	10.4	17.5	
Roach	9.2	22.4	14.1	10.4	12.2	7.6	12.1	17.9
Rudd	26.4	42.1	37.4	21.5	34.5	12.5	25.8	36.0
Bream		**32.0**	**57.8**	**23.6**	**22.7**	**29.8**	**89.1**	**430.0**
S-bream	7.0	12.5	14.6	12.1	12.8	8.7	11.9	14.3
Perch	9.4	10.0	18.8	18.2	12.5	7.3	12.0	19.0
Ruffe	11.6	16.4	14.0	8.6	11.2	14.8	16.0	

Table 18. Mean concentrations of mercury (Hg) mg/kg (dry weight) in the surface sediments (0-5 cm) of Gennarbyviken; north (N), central (C) and (south (S), and Sysilaxviken reservoirs at different depths in 1997-1998

Depth	Gennarbyv.(N)	Gennarbyv.(C)	Gennarbyv.(S)	Sysilaxviken
1 m	0.03	0.02	0.02	0.06
4 m	0.04		0.03	0.05
10 m		0.04		
17 m	0.08		0.08	
24 m	0.09		0.08	
32 m			0.11	

Table 19. Mean concentrations of iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), cadmium (Cd), lead (Pb) and nickel (Ni) mg/kg (dry weight), in the surface sediments (0-5 cm) of the two main depths in Gennarbyviken reservoir; north (N) 24 m and south (S) 32 m, in 1997-1998

METAL	Fe	Mn	Zn	Cu	Cd	Pb	Ni
24 m (N)	33500	730	210	35	0.99	27	100

Table 20. Concentrations of mercury (Hg), mg/kg (fresh weight) in muscle tissue of non-predatory fish; bleak (*Alburnus alburnus* L), smelt (*Osmerus eperlanus* L), bream (*Abramis brama* L) and predatory fish; ruffe (*Gymnocephalus cernua* L), burbot (*Lota lota* L), perch (*Perca fluviatilis* L), pike-perch (*Stizostedion lucioperca* L), eel (*Anguilla anguilla* and pike (*Esox lucius* L) from the Gennarbyviken and Sysilaxviken reservoirs in 1994-1998

GENNARBYVIKEN				SYSILAXVIKEN			
Fish species	Mean	Range	N		Mean	Range	N
Bleak	0.04		(5)	Bleak	0.05		(5)
Smelt	0.06	0.04 - 0.07	6	Smelt	0.15	0.07 - 0.22	28
Ruffe	0.26	0.11 - 0.39	10	Bream	0.18	0.06 - 0.31	6
Burbot	0.47		1	Burbot	0.40	0.40 - 0.40	2
Perch	0.52	0.36 - 0.69	5	Perch	0.52	0.49 - 0.55	6
Pike-perch	0.60	0.13 - 1.38	4	Pike-perch	0.91	0.31 - 1.32	4
Pike	1.58	0.28 - 3.68	5	Pike	0.85	0.25 - 2.12	9

Table 21. Mean concentrations of heavy metals, mg/kg (dry weight) in muscle tissue (M) and liver (L) of predatory fish; perch (*Perca fluviatilis* L), pike (*Esox lucius* L) and burbot (*Lota lota* L) from the Gennarbyviken reservoir in 1997-1998

METAL	Fe M/L	Mn M/L	Zn M/L	Cu M/L	Cd M/L	Pb M/L	Ni M/L	N
Perch	22 /130	2 / 9	23 / 88	3 / 15	0.22 / 2.10	0.1 / 0.1	0.1 / 0.2	3
Pike	8 / 98	2 / 7	35 / 145	2 / 11	0.01 / 0.72	0.1 / 0.1	0.1 / 0.1	5
Burbot	11 / 90	1 / 1	28 / 20	2 / 6	0.01 / 0.39	0.2 / 0.1	0.1 / 0.3	1

Table 22. Mean concentrations of heavy metals, mg/kg (dry weight) in muscle tissue (M) and liver (L) of non-predatory fish; smelt (*Osmerus eperlanus* L) and bream (*Abramis brama* L) and predatory fish; perch (*Perca fluviatilis* L), pike-perch (*Stizostedion lucioperca* L), pike (*Esox lucius* L) and burbot (*Lota lota* L) from the Sysilaxviken reservoir in 1994-1996

METAL	Fe M/L	Mn M/L	Zn M/L	Cu M/L	Cd M/L	Pb M/L	Ni M/L	N
Smelt	14 / 184	3 / 8	23 / 86	2 / 4	0.01 / 0.05	0.2 / 0.1	0.3 / 4.2	30
Bream	41 / 344	4 / 8	31 / 134	11 / 58	0.05 / 0.10	0.2 / 0.2	0.1 / 0.1	6
Perch	18 / 163	2 / 7	26 / 99	4 / 9	0.04 / 0.12	1.0 / 1.3	2.7 / 1.1	5
P-perch	14 / 132	1 / 3	18 / 50	1 / 4	0.01 / 0.01	0.1 / 0.1	0.1 / 0.1	4
Pike	29 / 189	1 / 5	64 / 174	2 / 14	0.01 / 0.05	0.1 / 0.1	0.1 / 0.1	9
Burbot	38 / 17	2 / 1	49 / 13	3 / 2	0.01 / 0.01	0.3 / 0.1	0.1 / 0.8	2

Table 23. Introduced fish (amount except for elvers of eel) into the Gennarbyviken reservoir in 1960--1996 according to data from Gennarbyvikens fiskevårdsförening 1996

Species	Pike	P-perch	Trout	W-fish	Vendace	Eel (kg)	Carp	Tench
1960		3500						
1962			1000		500 000	100 kg	2000	100
1967					1 000 000	30 kg	100	
1971	200 000							
1972	180000		1500				400	
1973	200 000						800	
1974	50 000		1300					
1975	120 000					150 kg		
1976				8000		300 kg		
1977				5750		300 kg		
1978		8100		20 000		400 kg		
1979				45 000		400 kg		
1981		2200		21 800				
1982				50 700				
1983		15 000		27 000				
1984		20 000		40 000				
1985		20 000		2800				
1986		19 000		30 000				
1988	395 000			1500 000				
1989	60 000	36 000	10 850					
1990	100 000		10 000			20 kg		
1991	150 000		10 570	6320		15 kg		
1992		2300	10 000			10 kg		
1993		2800	7000	3840				
1995	70 000		8240	5830				
1996	70 000	5000	7720					

Table 24. Mean concentrations (mg/kg d.wt.) of zink (Zn), copper (Cu), cadmium (Cd), lead (Pb) and nickel (Ni) in surface sediments (0-5 cm) of Finnish "headwater lakes", subregion "south" and the Gennarbyviken reservoir

METALS	Zn	Cu	Cd	Pb	Ni
Headwater Lakes	131	17	1.85	119	13
Gennarbyviken R	215	35	1.17	40	104